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PRODUCTION AND TECHNO-ECONOMIC OPPORTUNITIES OF USE OF WHEY IN INDUSTRIAL PROCESSES

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Abstract

Whey represents the least utilized by-product in the Serbian food industry, although it is very nutritious and poorly used in nutrition. More than a half of nutrients present in milk are also present in whey, including proteins (around 20%), wherefore it is considered as the most valuable product in nutritive sense. The first part of the article covers the statistical results, which show the production of milk and whey (whey in different forms of sale (a product code)) that occurs during the production of cheese in Serbia (2014-2017) and they comprise the results of a realized production, supplies at the end of the year and the quantity of sales. In the second part of the article the authors compared the obtained results, which were shown during the technological-economic profitability testing of the production plants: lactose and the whey protein concentrate, a functional drink based on whey and carrot during the production of cheese, as well as the whey protein bioactive hydrolyzes described in two scenarios, A and B, which have given a positive result in industrial production. There are numerous applicable techniques for the assessment of an economic profitability. The Super Pro Designer simulation software was used in this article for the results obtained. It is equipped with a wide spectrum of processes and is a powerful tool that can be used for the mathematical assessment of economic parameters.

Key words: *profitability, techno-economic analysis, whey, lactose, proteins*

INTRODUCTION

In the milk processing industry in Serbia, cow's milk is the most commonly used quantity in terms of quantity.
Today, goats and sheep milk are a significant market place. In recent years, Serbia has recorded an increase in the share of milk delivered to dairy farmers, which is over 60%, but still a significant amount of milk (about 35%) remains on farms for personal consumption, calving and processing into dairy products intended for the market which are mainly cheese, cream peppers in cream, vurda (cheese from whey) and the like (Table 1 and Table 2.).
Milk delivered to dairies is most often used as a raw material that has great potential because it can get a large number of products on the market [2; 3].
The paper also presents the amount of cheese production from which whey is produced after its production.

Table 1. Annual production and use of milk (all milk) in dairies in Serbia, in 2017 year

Availability (entry) of milk	Quantities (000 t)
Cow's milk (from farms)	862,082
Sheep's milk	0,201
Goat milk	0,514

Source: Statistical Office of the Republic of Serbia 2018 [12]

Cheese is one of the oldest forms of "preservation" of milk. It is a fresh or mature product that is obtained by clotting the protein in the milk with the extraction of whey and is one of the basic foods. According to the coenzyme, the cheese test, the amount of water and the method of production of cheeses can be extra hard, hard, semi-hard, semi-soft, soft cheese and cheese spreads.
During the acidic or enzymatic treatment of milk, cheese is formed, during which a large amount of whey is extracted during the process. This implies that in the practical

sense about 10.00 L of milk is consumed for the production of 1.00 kg of cheese, with 9.00 L of whey [13; 5; 1].

Table 2. Annual use of milk (all milk) in dairies for cheese production, in Serbia, in 2017 year

Cheese to hardness	Amounts (000 t)
Soft cheese	23,519
Medium-soft cheese	-
Medium-hard cheese	13,068
Hard cheese	2,103
Extra hard cheese	0,016
Fresh cheese	11,385
Processed cheese	1,798
Whey total	6,753
Surprise (liquid state)	2,632
Surprise (concentrated state)	0,031
Powdered powder or block	0,014

* The milk input is calculated on the basis of milk fat content
and proteins in dairy products.
Source: Statistical Office of the Republic of Serbia 2018 [12]

According to the results of research by scientists, the production of cheese has increased in the last few years, and the production of cheese has been shown to increase the world production of whey to an average of about 2% annually [11].

About 50% of the total obtained amount of world whey is treated and transformed into various food products, about 45.0% is directly used in liquid form, 30.0% in whey powder, 15.0% is used as lactose and the rest as protein concentrates [7; 9; 8]. In food and fermentation industry 50% of waste whey is used, while the rest are discharged into watercourses without previous processing which represents a very significant loss of nutritionally valuable raw materials [4; 6].

The other hand causes great environmental problems, considering high values of chemical oxygen demand, (COD) and biological oxygen demand (BOD). Considering the environmental pollution, the disposal of waste whey causes many problems, since it affects the physical and chemical soil structure, reduces crop yields, and discharging into watercourses leads to a high consumption of oxygen and death of flora and fauna [10; 12].

The production of three different production processes, where as the main raw material of whey, presents the techno-economic analysis of the plant for the production of lactose and whey protein concentrate, a plant for the production of a functional beverage in the process of cheese production, where, with a cost-effective production and use of the plant, and at the same time the amount of whey obtained is used to produce fermented juice in combination with carrot juice and the cost-effectiveness of the plant for the production of bioactive proteins of whey proteins [15]. Super Pro Designer software was used for all three cost-benefit testing of the plant.

MATERIALS AND METHODS

In the testing process for the analysis of techno-economic cost-effectiveness, Super Pro Designer software was used, which is a valuable tool for engineers and scientists.

It is equipped with numerous possibilities that meet the needs and the most complicated simulations and allows the user to simultaneously design and analyze the processes of production and economics of the entire project. The basic material in all three trials was used wheat as a raw material with 0.5% fat obtained from the dairy industry of Serbia [10; 14].

As a raw material, the whey left after the production of cheese and sterile skimmed milk with 0.5% milk fat was used.

In a particular software package, a model that has the basic characteristics of the real system is set, and by adjusting the basic parameters it is possible to analyze and predict the costs for many industrial processes. The investment appraisal as well as its alternatives is based on: economic indicators: net present value (NPV), internal rate of return (IRR), and period return of investment (PR). These indicators allow comparison of investment projects, techno-economic analysis and cost-benefit analysis: which includes a profitability analysis that can be done with or without time value of money, and sensitivity analysis: which implies the impact of the price of products and the capacity of the process on the indices of cost-effectiveness, capital investments, payback period, net present value and cash flow.

RESULTS AND DISCUSSIONS

In Serbia, of the total milk production, the largest amount is of cow's milk, 99%, which the processing industry redeeming for various types of processing products (Table 3).

Increase in production can be noticed, and with the increase in milk production, the quantities of milk products produced are also increasing. In year 2013 was taken as the base year and in relation to sit there is a slight increase in the production of cow's milk (by 55 million litters), which is the highest in 2017, which is 3.8% more, and also the litters of milk per bovine cow is on the rise compared to 2013, especially in 2016, which is 3.528 l, which is 8.7% more than in 2013 [10; 12]. Therefore, we have a higher average for five years, which are 3.4 litters per bovine cow (while the previous year the average was 3.1).

Table 3. The quantity of cow's milk produced in Serbia during the period 2013-2017

Year	Total cow milk (mil.liters)	Index - total production 2013=100	Litters per bred cow
2013	1,451	100	3,246
2014	1,491	102.75	3,269
2015	1,501	103.44	3,477
2016	1,504	103.65	3,528
2017	1,506	103.79	3,505
Average	**1,490**	**103.40**	**3,405**

Source: Statistical Office of the Republic of Serbia 2018 [12]

The total milk production in Serbia, about 92% comes from family farms, and the remaining 8% from social enterprises and cooperatives. Milk is delivered to over 50% of the total milk production in Serbia, and the rest is spent on farms, or sales in peasant markets, whether fresh or processed.

The structure of milk processing in the developed countries of the EU is in favour of durable global products such as permanent cheeses, milk powder and butter. Based on this change in the production structure, it can be expected in favour of the production of various types of cheese, yoghurt and other fermented milk drinks that already generate higher profit on the market and satisfy the market demand.

In Serbia, whey remains one of the insufficiently used by-products of the food industry. Due to its non-use, whey becomes a very big polluter, which is in complete disagreement with the potentials it possesses.

Table 4. Realized production, stocks and sales of industrial products (whey*) in Serbia during the period 2013-2017

Product code	Production achieved (tons)	Inventories at the end of the year (tons)	Sale (tons)
1051.55.30	145	0	59
2014			
1051.55.30	313	4	194
2015			
1051.55.60	306	1	186
2016			
1051.55.60	690	2	692
2017			
1051.55.60	547	0	549

*Surprise and modified whey powder, granules and other
Solid forms, whether concentrated or not concentrated, sweetened
Source: Statistical Office of the Republic of Serbia 2018 [12]

According to the data from Table 4, it can be concluded that the realized production of whey in different rituals is growing in the Republic of Serbia from 2013 to 2016. However, in 2017 only 79.3% was produced in comparison with the previous year, which is for 20.7% less.

In table 5 were given the economic parameters for all three different production processes, i.e. the techno-economic analysis of the cost-effectiveness of the production plant, and the results of total investments, the repayment period, the internal rate of return and net present value were determined. According to the established amounts of indicators, this product is economically justified.

Table 5. Display of economic parameters of factories for analyzed scenarios

Economic Parameters	Lactose and concentrate whey protein	Integration Cheese / whey - Carrot juice	Scenario A	Scenario B
Total invest ($ 000)	20,985	210,51	22,940	17,402
PR (year)	1.59	0.15	3.06	0.09
IRR (%)	45,86	10,464	17.73	230.55
NPV ($·10^6)	68,118,000	384,61	25,38	1,635,5

Source: Author's calculation obtained by program SuperPro Desinger [2]

From the results obtained for a lactose production plant with a basic capacity of 1,000 kg h^{-1} total capital investments amount to 20,985,000 dollars. Since the repayment period shows the length of the period during which the invested funds will be returned, this test is 1.59 per year. This is a very short period of time, which shows that it will be faster to raise funds that can be used for other purposes. The internal rate of return (IRR), after tax, is 45.86%. This rate is far higher than the average size of the decision to accept the project. Net present value (NPV) means that investment in the added value of products, i.e., processing whey is economically justified and can be accepted.

Other tests related to the techno-economic analysis of the cost-effectiveness of the plant for the production of functional drinks based on whey also indicate that this production has acceptable parameters that lead to the integrated production process of cheese / beverage production of whey and carrots more economically viable than the basic process of cheese production.

Due to excellent economic indicators, the integrated process of cheese /beverage production of whey and carrots allows for a faster return on capital of 0.15 years (PR), with higher NSV of 10,464.04 $ and IRR with values of 384.61%.

A plant that simultaneously produces cheese and whey and carrot beverages is economically more attractive compared to a plant that produces only cheese.

The cost-benefit analysis of the plant for the production of bioactive hydrolyzes of whey proteins included two possible scenarios:
- Scenario A which implies the use of whey;
- Scenario B, which implies the use of whey concentrate as a source of protein.

Total capital investments for a factory with a base capacity of 1,000 kg h^{-1} amount to $ 22,940,000 for Scenario A, while Scenario B is $ 17,402,000. If taken to analyze that the sales price of the bioactive protein hydrolyzes of whey protein is $ 20 kg-1, scenario A obtains an internal rate of return on investment (IRR) of 17.73% and Scenario B is 230.55%. With a discount rate of 7%, the net present value (NSV) for scenario A is $ 25.38 million and $ 1,635.6 million for Scenario B. Based on the results obtained, it can be concluded that scenario B represents much more attractive investment than the Scenario A. The results obtained conclude that scenario B indicates that enzymatic modification of whey proteins is a highly profitable business in the production of bioactive hydrolyzes of whey proteins [2].

The payback period for scenario B is 0.09 years and much shorter than 3.06 years for scenario A. According to the obtained results, this way of processing whey is very profitable, and especially economically justified processing according to scenario B.

Taking into account all three of the above-mentioned techno-economic solutions, the exploitation of whey by transforming it into added-value products based on whey proteins are processes that offer an environmentally acceptable and economically viable solution.

CONCLUSIONS

It is known that whey is very rich in vitamins, minerals and especially proteins and lactose. Part of the money spent on dumping whey can be directed and profit. That's why there are many opportunities for the exploitation and use of whey today.

A significant amount of money spent on the dumping (dumping) of whey can be converted into profit. This can be done through the production of functional value-added products, such as:

-Concentrated protein WPC;
-Lactose powder LAC;
-The possibility of using carrot juice in the production of functional;
-Fermented beverages based on whey;
-Obtaining to bioactive protein hydrolyzes of whey protein, etc.

The evaluation of investments as well as its alternatives is based on economic indicators: net present value, internal rate of return and period on investment returns.

All presented results obtained using the licensed software Super Pro Designers indicate the profitability of the use of whey in the process of processing the dairy industry, since all processes represent a double solution for waste management as well as the economic potential for dairy development in Serbia.

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